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On structures and control methods of joint streams regulation by two water power developments in satisfying water consumers' demands

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Abstract

The paper describes basic characteristics and maintenance conditions of Umaguzin and Nugush water power developments which were built in the Republic of Bashkortostan, Russia, in different time periods. The importance of water reservoirs formed as a result of their construction is stressed. The research shows the peculiarities of work, gives technical characteristics of these storage control structures and defines their key role in regulation of streams. Interrelationship of operating stages in the work of storage control water power developments is also underlined. As an example, the authors present their determinations of intermediate inflow coefficient of water flow. The paper reviews water consumers' demands for joint regulation of water course by different water power developments and for level-based operation of their joint afterbay. Some recommendations for satisfying these demands are given and economic effectiveness of these recommendations is estimated.

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Keywords: Low-head water power development; Water reservoir; Culvert; Storage control; Water-level; Water consumer.

1. Introduction

Lowland river water power developments are usually built to solve several problems, so they are basically described as multipurpose waterworks units [1-3]. Their work is based on sustainable use of water resources stored

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in water storage basin and is aimed to satisfy various water consumers' demands [4-7]. Operational procedures of such multipurpose hydraulic structures take into account both these water basins actual capacities and their water carrying capacities on the basis of their safe use [8-14].

When water consumers' demands are satisfied by several water power developments located in joint downstream it becomes more difficult to regulate river stream flow. Such conditions exist in the Republic of Bashkortostan, Russia, in the middle flow of the Belaya River. There are two water power developments (Umaguzinskiy and Nugushskiy) here and both of them have considerable impact on the formation of level mode and downstream consumers' water supply.

The paper analysis the possibility of satisfying water consumers' demands by joint regulation of water course by two different water power developments (Umaguzinskiy and Nugushskiy).

2. Research

The peculiarities of Umaguzinskiy and Nugushskiy water power developments lie in the fact that their retaining structures and water storage basins are located on the territory of the National Park "Bashkiriya", which is also of the Federal importance. Figure 1 shows the National Park borders. The cities of Meleuz, Salavat, Ishimbay and Sterlitamak are situated in these water power developments joint downstream.

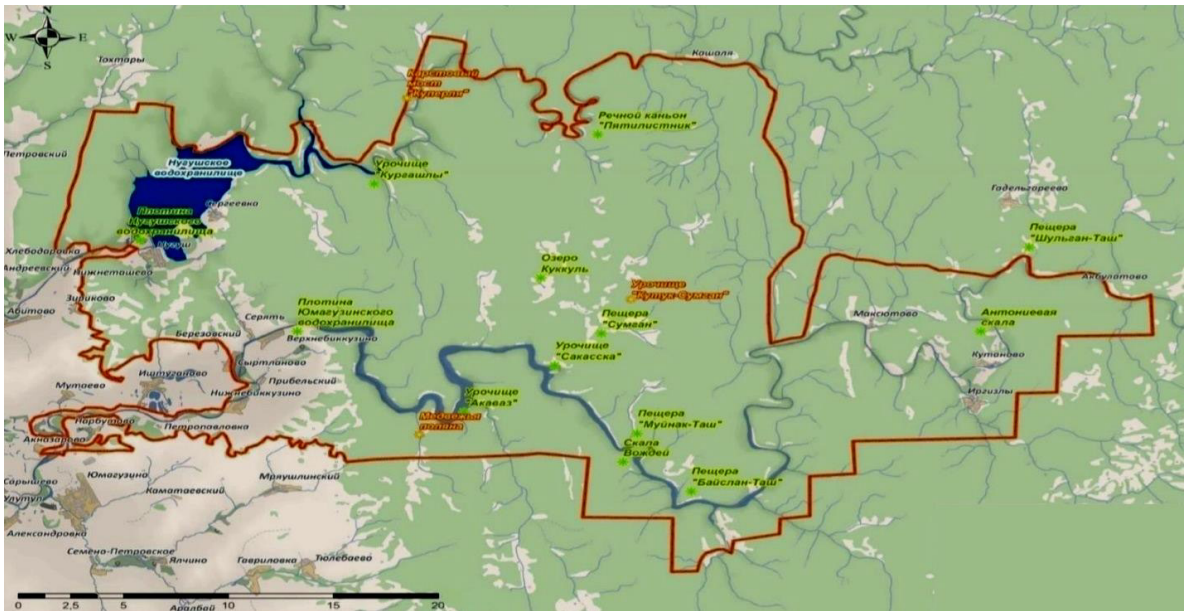

Fig. 1. Umaguzinskiy and Nugushskiy water power developments on the territory of the National Park.

The main demands of the water consumers here are as follows: 1 – to protect waterfronts of the towns and oil refineries from water flooding in flood season; 2 – to prevent lowering of the water level to the bottom value necessary to enable industrial enterprises (those situated along the downstream side of the rivers) run effectively; 3 – to generate electric energy for the towns and industrial enterprises.

Nugushskiy water power development was being built from 1961 to 1967. Its water storage basin has useful storage capacity of 365 ml m^3. Its length is 29 km and its maximal width is 5 km. The water basin is located on the Nugush river and is surrounded by stiff slope barrows. Water drawdown here starts at 17.4 m (normal headwater level being 217.0 m). This water power development consists of the phreatic dam, the hydraulic engineering structure power room (run-of-river-type with three hydraulic turbines), left shore spillway, submerged outlet combined with hydraulic engineering structure water tunnel (see Fig. 2).

Fig. 2. Structural plan of Nugushskiy water power development [15].

This water power development controls water stream while passing water flow up to 50 m^3/sec firstly through two water tunnels (2.4 m diameter) of submerged outlet and then through hydraulic engineering units (including regulating releases). It also controls water stream while flood discharging through four channel type spillways of shore-based floodway (its carrying capacity being 1200 m^3/sec (see Fig. 3).

Fig. 3. The supercharger dam of Nugushskiy water power development [15].

The 1990 was the year of the rarest 0.5% supply in the work period of the waterpower development in question. The use of the hydrological forecast, sustainable use of water resources, measures to provide flood peak reduction, careful setup of water basin storage capacity made it possible to satisfy the demands of the water consumers and to prevent more than 1200 m^3/sec water discharge (see Fig. 4). Still this flow rate proves that this water basin usable storage capacity is not high enough.

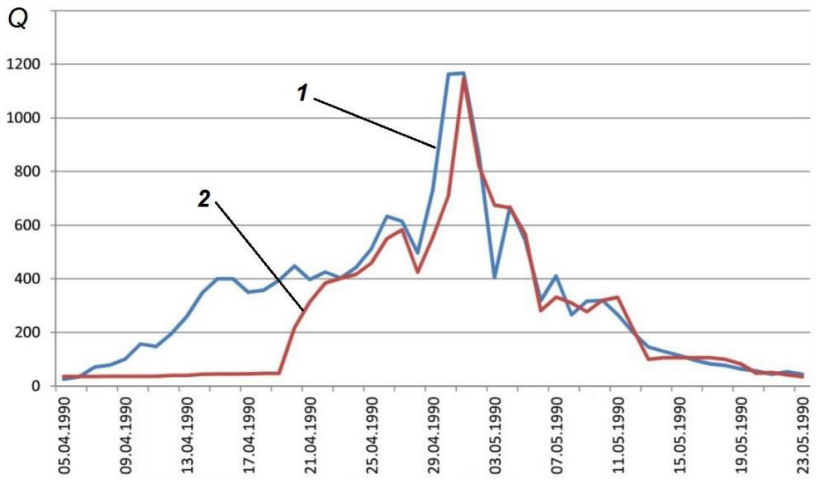

Fig. 4. The schedule of water pass through Nugushskiy water power development during spring flood, 0.5% supply: reservoir inflow (1), discharge into downstream (2) [15].

In operating Nugushskiy water power development the greatest problems arose in low water and average water years. Figure 5 shows the water passage schedule in 1975 (low water year). Flood season water discharge was 27 m^3/sec while the usual headwater level was not reached. The demands of downstream water consumers (40 m^3/sec) were nor satisfied.

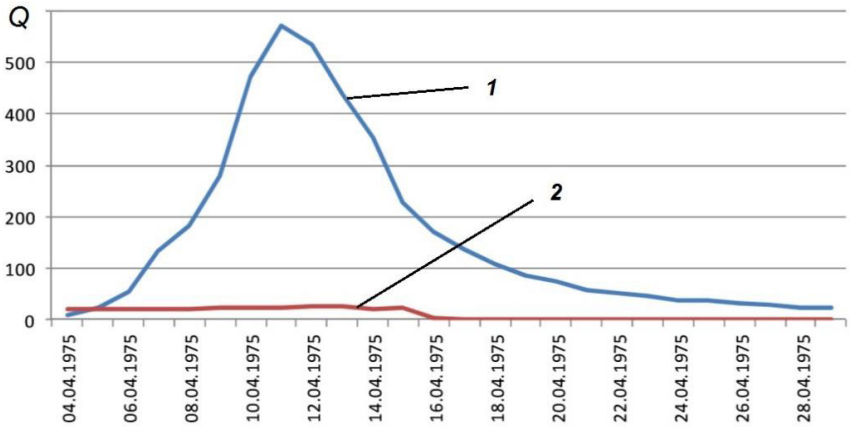

Fig. 5. The schedule of water pass through Nugushskiy water power development during spring flood, 90% supply: reservoir inflow (1), discharge into downstream (2) [15].

To battle this problem the Bashkortostan authorities took a decision to build Umaguzinskiy water power development. Joint streams regulation of the Nugush River and the Belaya River flows had a key role in satisfying downstream water consumers' demands.

Umaguzinskiy water power development was being built from 2003 to 2007. It includes a rock-fill dam which is 63m height and 605 length and which blocks the river right when it passes the barrows. Its water storage basin has

useful storage capacity of 435 ml m^3 and it is located in a narrow dale (see Fig. 1). It was possible to avoid large area flooding.

This water basin is stored mostly by means of snow melting. The design water discharge with 1% and 0.1% supply is 2470 m^3/sec and 3455 m^3/sec respectively. The water basin is used to regulate water flow, both short-time (daily and weekly) and annual (seasonal). The water basin maximal decrease of storage can reach 35 m.

Umaguzinskiy water power development has the following water sluices to control water stream: submerged flood-discharge outlet and combined with hydraulic engineering structure water tunnel and shore flood spillway.

The hydraulic engineering structure power room is that of appurtenant structure and is located on the left shore of the river. Three hydraulic turbines have the maximum 130 m^3/sec water flow capacity and provide installed capacity of 45 kVt with rated head of 40 m. The water flows through three tunnel pressure turbine passages (with 3.2 m diameter). Its maximal water flow capacity of flood-discharge outlet is 1465 m^3/sec and can be reached only in overflow spring flood-time. Figure 6 shows tailrace canals and submerged flood-discharge outlets.

Fig. 6. The hydraulic engineering structure tailrace canals and submerged flood-discharge outlet.

The maximum water carrying capacity of this water power development right bank flood spillway is 2300 m^3/sec. It is the main operating flood spillway. Its intake portal presents a spillway with four 9 m wide passes. The spillway runner presents a 45 m wide channel (see Fig. 7).

The general water carrying capacity of this water power development is 3895 m3/sec. It provides the required intensity of water flow (0.1% supply).

At the moment water consumers' demands for joint regulation of water course by Nugushskiy and Umaguzinsliy water power developments are not satisfied completely because downstream flood protective structures have not yet been set into operation. That's why it is also important to develop new methods of operating water basins and water-regulating structures (with joint downstream water area) under conditions different from project specifications.

To solve the problem of satisfying up- and downstream water consumers' demands we had to analyze and take into account the following factors. Firstly, one had to take care of the structures and constructions located in the flood water zone on the one hand; and of the industrial enterprises, consumers of electric power, recreation resources suffering lack of water in low streamflow period, on the other. Secondly, the location of the water basins (the National park) had to be taken into account.

Fig. 7. Riverside floodway [16].

The special attention was given to the following factors: 1 – expected water levels accuracy increase (taken in monitoring sections and based on empirically determined drain coefficient); 2 – intermediate inflow influence on hydrological conditions change in the downstream.

The undertaken research allowed to identify the boundary operating conditions for Umaguzinskiy and Nugushskiy water power developments during the worst flood-time (2007). The overall results are as follows:

- The maximum acceptable waterflow in Sterlitamak water abstraction point when regulated by Umaguzinskiy and Nugushskiy water power developments and on condition that downstream flood protective structures have not yet been set into operation is max 1500 m^3/sec (design calculation is 2200 m^3/sec);
- The minimum required water flow rate in Sterlitamak water abstraction point (40 m^3/sec) is not provided in low-water period of low water years (2009, 2010, 2012).

Yet the investigation on new methods of operating two joint water basins was conducted while taking into account the following design restrictions:

- As Umaguzinskiy water power development has not yet been set into operation to the full extent, the maximum water filling and water drawdown speed was not more than 2 meters a day;
- The shore-based floodway of Umaguzinskiy water power development time restrictions: it was allowed to discharge water only when the water basin level was at least 260 meters high;
- The shore-based floodway of Umaguzinskiy water power development height restrictions: floodhatch should be lifted not higher than 1 meter;
- The submerged flood-discharge outlet restrictions: to lengthen the operating period of this hydraulic engineering structure turbines the intensity of waterflow should be not more than 300 m^3/sec;
- Umaguzinskiy water power development full capacity restrictions: upstream level 265 meters;
- Umaguzinskiy water power development time restrictions: water level increase is allowed to be kept above the maximum level for 10 days only (in order to preserve flora in the conservation area);
- Nugushskiy water power development restrictions: it is strictly required to fill the water basin up to the full reservoir level to create optimal conditions for fish-breeding and recreation.

If these conditions are satisfied and all the restrictions are taken into account it is possible to achieve top performance of Nugushskiy and Umaguzinskiy water power developments in regulating water flow even in the case when water-management functions in the Belaya River middle flow are not fully performed.

We estimated the new improved methods of operating two joint water basins efficiency and came to the following conclusion. During the year of the worst flood-time (2007) the apparent economic benefit that accrued as

a result of national economy damage reduction figured up to 375 ml roubles a year. The apparent economic benefit that accrued as a result of the new improved methods for low-water period regulations figured up to 397 ml roubles. In total, the apparent economic benefit that accrued as a result of the new improved methods for regulating joint water basins figures up to 772 ml roubles a year.

3. Conclusions

The research yielded the following conclusions:

- Umaguzinskiy and Nugushskiy water power developments (built in the Republic of Bashkortostan on the Nugush River and the Belaya River respectively) perform joint streams regulation and are used to satisfy downstream water consumers' demands;
- Umaguzinskiy and Nugushskiy water basins and hydraulic structures provide a means for water retaining in flood periods and downstream water passage as required;
- The investigation on joint water power developments showed that their operating conditions should be regulated according to the amount of flood-protection works performed. For that purpose, the authors introduced new improved methods of operating joint water basins. These methods provide both efficient use of water resources and minimal damage for water consumers.

References

[1] M.I. Balzannikov, Priority fields of developing renewable power in the Middle Volga region, Proceedings of Voizhskiy Regional Section of the Russian Akademy of Architecture and Construction Sciences. N.Novgorod: izd-vo Nizhegorodskogo gos. arkh.-stroit. un-ta. 2005. № 8. pp. 173-185 (in Russian).

[2] M.I. Balzannikov, Power plants based on renewable energy sources and their impact on the environment, Vestnik Volgogr. gos. arkhit.-stroit. un-ta. Stroitelstvo i arkhitektura. 2013. № 31(50). Part. 1. pp. 336-342 (in Russian).

[3] M.I. Balzannikov, S.V. Evdokimov, Yu.M. Galitskova, Development of renewable energy generation as an important contribution to environmental protection, Promyshlennoe i grazhdanskoe stroitelstvo. 2014. № 3. pp. 16-19 (in Russian).

[4] M.I. Balzannikov, V.V. Elistratov, Renewable energy sources. Aspects of complex use. Samara: SGASU. 2008. 331 p.

[5] M.I. Balzannikov, Basis for installed capacity of HPP in hydroelectric system, Higher education news. Construction. 2014, № 8. pp. 32-40 (in Russian).

[6] R.F. Abdrakhmanov, V.A. Tyur, V.M. Yurov, Yumaguzinskoe vodokhranilishche. Yumaguzinskoe water reservoir. Development of hydrological and hydroclimatic regimes. Ufa, Informreklama, 2008. 152 p. (in Russian).

[7] R.F. Abdrakhmanov, B.N. Batanov, V.A. Tyur, V.M. Yurov, Operating practices of the Yumaguzinskoe water reservoir, Amelioration and water economy. 2009, № 4. pp. 27-29 (in Russian).

[8]. S.V. Evdokimov, T.V. Dormidontova, Criteria for assessment of reliability and technical conditions of hydrotechnical structuresVestnik of SSUACE. Town Planning and Architecture, 2011, № 2. pp. 105-109. doi:10.17673/Vestnik.2011.02.23 (in Russian).

[9] S.V Evdokimov, T.V. Dormidontova, Assessment of reliability of hydraulic structures, Vestnik of SSUACE. Town Planning and Architecture, 2012. № 1. pp. 49-53. doi:10.17673/Vestnik.2012.01.12 (in Russian).

[10] S.V. Evdokimov, Safety problems in construction of power systems using non-traditional (renewable) energy sources, SGASU herald. Urban planning and architecture. 2012, № 2, pp. 68-74. doi:10.17673/Vestnik.2012.02.13 (in Russian).

[11] M.I. Balzannikov, V.A. Zubkov, N.V. Kondratjeva, V.A. Khurtin, Complex inspection of the technical condition of components of structures at the Zhigulevsk HPP, Power Technology and Engineering (Springer New York Consultants Bureau). 2013. T. 47. № 4. pp. 267-272.

[12] M.I. Balzannikov, S.M. Shakarna, Probability evaluation of slope stability in earth dams, Vestnik of SSUACE. Town Planning and Architecture], 2011. № 1. pp. 92-95. doi:10.17673/Vestnik.2011.01.18 (in Russian).

[13] M.I. Balzannikov, M.V. Rodionov, V.A. Seliverstov, Increasing the environmental safety of earth hydrotechnical structuresVestnik of SSUACE. Town Planning and Architecture, 2011, № 1. pp. 100-105. doi:10.17673/Vestnik.2011.01.20 (in Russian).

[14] Svitala F., Galitskova Y.M., S.V Evdokimov, Specifics of construction of hydrotechnical structures and operational buildings in primary hydro power plants. Industrial and civil construction. 2014, № 12. pp. 87-90.

[15] http://www.regulation.gov.ru/get.php?view_id=3&doc_id=26960 [Available on-line], 17.03.2015.

[16] M.I. Balzannikov, V.M. Yurov, A.A. Mikhasek, Pecularities of co-regulation of river flow by multipurpose hydraulic structures. Scientific survey. 2015. № 3. pp. 101-108.